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BRIEF REPORT

SOME GERMAN UNDERGROUND MUNITION STORES AND FACTORIES IN FRANCE AND LUXEMBURG

by

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Ministry of Home Security, Research and Experiments Department

Investigating party dispatched by R.R.R.M. - February, 1945

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SECRET

RAID REPORT ON

SOME GERMAN UNDERGROUND MINERALS STORES AND FACTORIES IN FRANCE AND LUXEMBURG

SUMMARY

This report describes nine underground places used by the Germans for storage or manufacture, all but one of which were established in existing quarry tunnels or mines. A partial survey of the St. Leu d'Esserent workings was made, since this place was subjected to air attack, the results of which are discussed. A sketch plan shows the entrance to tunnels at Tavernay, where S.K.F. ball bearings were being made, and plans of a V.1 bomb factory in an iron mine in Luxembourg are included. Brief accounts of the remaining six places, which were visited in passing, are given.

The report, which is accompanied by 7 figures and 24 photographs, concludes with a section in which are analyzed the thickness of overhead cover deemed adequate by the Germans, the minimum size of bomb likely to be effective in causing damage inside the tunnels when penetrating the surface over the tunneled area, and the form of air attack which, as a result of examination of the sites, seems likely to prove the most effective in each case.

1. NOTES ON PLACES VISITED

1.1 Orival

At Orival, about nine miles south-west of Rouen at the foot of a chalk cliff on the banks of the Seine, the Germans were preparing what the local inhabitants understood was to have been a store for V bombs. At this point the hills terminate in a vertical cliff over 100 ft. in height, leaving a narrow ribbon of land between the cliff and the river, approximately 100 yd. in width. A number of houses existed within 70 ft. of the cliff face and between them and the river ran a road.

The Germans, in order to exploit the existing caves, excavated the ground between the houses and cliff to a depth of 3 to 4 ft. and laid a concrete road. The houses were left intact and the inhabitants allowed to live in them. The concrete and all new work were heavily camouflaged in the normal manner. The workings, which could not be inspected in detail, consisted of several headings driven into a cliff. Many of them do not extend very far into the cliff and were used for stores of petrol, etc. Protective walls built of 13 $\frac{1}{2}$ in. brick were observed at the entrances to these short tunnels. In the entrances to the two main tunnels, however, substantial masonry walls about 6 ft. thick, making dog-legged entrances had been constructed. These main workings could not be inspected so the presence or otherwise of further walls could not be ascertained.

1.2 St. Leu d'Esserent

1. Summary

This site, situated in a limestone escarpment close to the Cise, was attacked by a mixed force of 200 Halifaxes and Lancasters on the night of 4/5 August, 1944. In this attack, 500 lb. and Tallboy (Y) bombs were used.

Although numerous "throughs" were obtained into an upper series of connected tunnels close to an entrance it was found that these tunnels were not used by the Germans. The main workings had been little affected by the bombardment and except for spalling at weak bedding planes little damage attributable directly to the raid could be observed.

1.3 St. Leu d'Esserent

1.4 Tavernay

- b. Extracts from Notes of Air Commodore C.M.H. Bilney, O.B.E., on certain targets bombed by Bomber Command.
- c. Interpretation report No. X 07(2) dated 27.7.44.
- d. Note on an examination of certain bombed targets in France 1003/415.

In addition other geological data were available, and interpretation from air cover had been made by Ministry of Home Security, R. & E. Department (20.8.44).

.3 Site and general description

The carrière (tunneled quarry) used by the Germans is situated below the calcaire grossier supérieur in the calcaire grossier moyen et inférieur, which is a soft medium-grained limestone, 8-10 m. thick, in the western escarpment on the banks of the Oise. The escarpment at St. Leu is some 120 ft. high, and the entrances are approximately 40 - 50 ft. above the floor of the valley.

The carrière, originally started in the 10th century for quarrying, was used before the war for mushroom growing. The stratum worked appears to be the " banc St. Leu" which is a homogeneous compact bed about 5 m. thick; hence the galleries vary from about 3 - 5 m. in height. The quarrying was done on the "stoop and room" system, leaving pillars 3 - 5 m. square. In most places the roof appeared to be sound and free from spalling. Vertical shafts approximately 2 ft. 6 in. in diameter were driven down to the tunnels for ventilation purposes. In addition to this series of tunnels, another and smaller series existed over the southern half of the main galleries.

After 1940 the Germans used the lower caves for storing bombs, and constructed a concrete road up to the loading point, together with a railway line running parallel to the new road. Gantries were constructed to facilitate the discharge of goods from the railway to road trucks. The railway and roads were heavily camouflaged with wire netting covered with brushwood.

In addition, before the carrière was used for V.1 bombs the whole floor was concreted. Reinforced concrete gun emplacements were erected at the two approaches (Photograph No. 1), and heavy concrete doors erected across the northern or main entrance (Photographs No.s 2 and 3).

The part of the carrière used by the Germans was only a small portion of the whole system, the factory being sealed off from the main system by cement rubble walls about 2 ft. thick. The total area was approximately 700,000 sq.ft. of which about half was taken up by columns left in to support the roof.

There was also evidence in some places that rubble walls had been built close to the escarpment, where the cover was not so great, to give greater protection to the rest of the factory. The open air vents, constructed by the French, had been sealed off on the surface by concrete blocks, the open vent being replaced by four smaller vents issuing out of the side of the block.

For details of the layout of the factory see Figs. 1 and 2.

.4 Use of the tunnels

The lower level tunnels were used for the assembly of the main units of flying bombs. The components were brought up by rail and discharged into trucks which finally delivered into the factory. The assembled flying bombs units were taken out by night on lorries for transference to the forward areas. No indication of the vicinity of the factory could be found.

The personnel employed by the Germans were said to have been Russian and political prisoners.

.5 Cover

This is a short note on the methods of cover used by the Germans. In

- 3 -

to only 40 ft., due to subsidence into the top series of tunnels over the first 300 ft. from the entrance. This subsidence was of old date, as were several other smaller depressions on the top of the escarpment. The cover increased up to about 80 ft. as the tunnels entered into the hill.

5 Protective walls

There was no indication of the use of blast or protective walls, other than those which had been built close to the edge of the escarpment, as already noted.

The factory was sealed from the rest of the carriage by 2 ft. rubble walls. The ventilation shafts were similarly sealed off, leaving grilles approximately 3 ft. square, close to roof level.

The main entrance was protected by two solid concrete doors in steel frames each 15 ft. 6 in. by 9 ft. by 3 ft. thick (Photographs Nos. 2 and 3). There was no indication of any other doors.

7 Attacks

On the night of the 4/5 August, 1944, Bomber Command attacked the site with 200 Lancasters and Halifaxs carrying 1000 and 500 lb. bombs together with 11 Tallboys (M).

Numerous hits on the target area were obtained by the 1000 and 500 lb. bombs, but only one Tallboy (M) crater could be found in the vicinity. The latter was of normal dimensions (100 ft. by 30 ft.) but it was not over the portion of the carriage used by the Germans.

8 Result of the attacks

The whole area from the top of the escarpment to the river Oise was covered with craters. Over the southern half of the factory area (which, it must be remembered, is in the lower level tunnels) there were several "throughs" into the upper level tunnels. These are shown in detail in Fig. 2 and in Photographs Nos. 5 - 8. It was evident that at the date of inspection (6 months after the attack) they were of a very much larger size than they had been when first made. The cover near the escarpment at crater No. 1 was 24 ft., and at crater No. 4 it was approximately 35 ft.

It would seem likely that the bombs had burst above the roof of the upper level tunnels and blown through. There was also a very large area (south of that used by the Germans) of subsidence into the upper series of tunnels. This area was not examined in detail because it was in a protective minefield. The cover over this section was less than that already noted over the remaining position. There were indications of minor subsidences without any apparent trace of bombs. It was evident that this portion over the upper series of tunnels was relatively unsafe, since subsidence had taken place naturally from time to time in the past.

The floor of the lower series of tunnels used by the Germans was littered in certain places by small and large pieces of limestone. An inspection of the roof usually revealed some weak bedding plane. It was impossible to relate those minor falls to any specific bombs, or even to the bombing; at all, since the Germans had carried out extensive demolitions by blowing up the remaining flying bombs before departure (see Photographs Nos. 9 and 10). The falls might be attributable to the blast from the explosion of these bombs.

Whether or not these falls were caused by bombs they were stated by the French to have had little effect on work in the tunnels, which continued normally.

9 Comparison with interpretation

An interpretation of this report had been made on 22.8.44 by G. G. G., which is as follows: "The report, first to be compiled in U.S. 11th Army Group, is based on the examination of the site by the Germans, and is not to be regarded as final. It is based on the assumption that the Germans have not been able to make any major changes in the site since the inspection made by the Germans on 10.8.44."

This was found to be the case. An upper series of tunnels existed which had not been used by the Germans. "Throughs" had been obtained into the upper level tunnels, but the blockages caused were only local, and the damage was confined to these isolated areas in the upper level tunnels.

1.0 Conclusions.

The attack showed that 1000 lb. bombs are adequate for causing subsidence and "throughs" into tunnels covered with up to 35 ft. of top soil and limestone, but that they are ineffective against tunnels with 60 ft. of soft limestone cover. To gain any success against a target of this nature Tallboy (M) bombs would have to be used, and even these, apart from being dropped over the main entrances so as to block them, would be of limited use, since in tunnel systems so interconnected it would always be possible to go round any local blocks and falls.

Tallboy (M) should be fused to ensure maximum penetration before detonation - hence there should be no objection to using even 11 sec. delay. In any case, however, it is unlikely that Tallboy (M) would penetrate far enough into the 60 ft. of soft limestone cover for serious blast effects from detonation to occur inside the lower level tunnels.

1.3 Trossy St. Maximin

This open quarry, with old tunnel quarries below, is on the left-hand of the river Oise, nearly opposite St. Leu d'Esserent. A quick inspection was made when en route for the latter site, during which no measurements were taken. As shown in Photographs Nos. 11 and 12, very large diameter shafts, lined and roofed with thick reinforced concrete, were being constructed by the Germans through the relatively thin limestone cover over the top of the old quarry tunnels. The appearance of the work suggests that large storage tanks - possibly for oil - were to have been installed.

1.4 Taverney (visited on 2.3.46)

At Taverney, about 10 miles north of Paris, there is an extensive system of quarries tunnelled into "middle calcaire grossier" from a double entrance on level ground into a cliff face which rises to about 120 ft. at about 130 ft. in from the entrance (see Fig. 3 and Photograph No. 13). The overhead cover consists of layers of marl and thin-bedded limestone.

The Germans converted part of these tunnels for use as a factory, and transferred there plant from the S.M.F. ball bearing works in the south of Paris. There is no evidence of any air attack on the Taverney tunnels. It is understood that at the time of the Allied invasion the manufacture of ball bearings had been started, but that the Germans destroyed all material before evacuating Paris.

A brief inspection of these tunnels, which are of the high gothic cross section common to the Paris carrières, showed that the Germans had constructed concrete portals at the twin entrances (camouflaged by netting, now destroyed), and lined the two parallel main tunnels, which run straight in for two or three hundred yards without any form of blast protection, with concrete for the first 130 ft. - i.e., to where the overhead cover approaches 100 ft. At various places the connexions to side chambers and other tunnels had been walled up - possibly to regulate natural ventilation as well as to enclose the factory area. At several places in the factory area there is evidence of fire (which local French said were oil fires in which the Germans destroyed material). These fires, in some cases had caused spall-off and falls of rock from the roof. The French said also that a few mines and booby traps were left in the tunnels by the Germans, but that these were removed by the U.S. Army when the remains of the plant were being taken out.

1.5 Montrechard

1. Location

Very evident, in the "Champagne of Loire" in the Orléans area, is the extensive system of tunnels and quarries developed by the Germans during the war.

which are in soft limestone ("pierre de manier") are understood to extent for about 5 km. Under the hills, the main entrance to the portion used by the Germans (see Photograph No. 14) being about 2 miles east of Montrichard, a few hundred yards up a turning to the north of road C.40. Practically all building stone for local use is, and has been for centuries, obtained by quarrying in tunnels of this type, the tunnels being used subsequently for wine storage and the cultivation of mushrooms.

A brief inspection of the tunnels used by the Germans was made on 9th March, 1945, which on arrival of the party, proved to be under French military guard, despite information to the contrary from the military authorities in Tours. Some persuasion was required to gain admittance under escort, and since it was not possible in the circumstances to take measurements, much of the information hereunder should be accepted with reserve, since it was obtained from local French civilians.

.2 Description

The Germans utilized about 60,000 sq.m. of floor space and closed off the area by 1 m. thick masonry walling in cement mortar. Substantial masonry piers were built at places to shorten excessive roof spans.

The tunnels appear to run in haphazard directions with frequent cross connexions. They are rectangular in section, averaging 4 m. wide x 3 m. high, and are not lined. There is access for lorries to a loading bay about 50 m. within the entrance. The Germans did not erect blast doors or traverses presumably since the existing deviations from the straight of the tunnels at and beyond the entrance were deemed to give sufficient protection.

The overhead cover is about 20 m. thick at a point a short distance within the entrance, and rises to a maximum of about 40 m. (of which the upper 15 m. is clay - see below).

During the inspection the tunnels were observed to be still full of munitions, both German and (doubtless captured) French. Bombs of medium and small sizes (such as 50 kg.) appear to predominate, although there was much S.A.A., and numerous hand grenades were lying about. A large stock of French 75 mm. shells was noticed, it being said that these tunnels contained as many as 100,000 of them.

.3 Demolition

The U.S. troops arrived on 8th September, 1944. The Germans had left on the 1st September, after having attempted to blow up this arsenal on 20th August by detonating bombs and charges at various positions in the tunnels. At the time of our visit the resulting roof falls and tunnel blocks were being laboriously cleared by French civilian workers - a hazardous procedure, since munitions of all sorts lay scattered about beneath rock falls. In a number of places the tunnels are completely blocked, so a complete tour could not be made.

As a result of the demolition explosions several blow throughs to the surface occurred. A large disturbance in the surface, which was said to be in a position where the ground consists of 15 m. clay, and then 20 m. of soft limestone above the tunnel roof, was inspected. The French said that in these explosions small bombs were ejected which, in falling back, made small splash craters in the vicinity of the main craters. This is improbable; it is much more likely that these small auxiliary depressions were caused by gases from the explosions escaping under pressure through fissures in the ground.

The ground surface over the tunnel area used by the Germans was ringed with barbed wire and patrolled at night by soldiers with dogs to keep off spies and the requis.

.4 Conclusions

This important underground installation was not subjected to air attack, probably because the Germans did not have had time to finish it, and the French did not consider it worth the effort to do so.

point, perhaps 20 ft. from a tunnel. The resistance of this very soft limestone is probably no greater than that of very good chalk, and since the observed effects of Tallboy (M) in the chalk above the extensive tunnelling done by the Germans in the Pas de Calais area (e.g., at Marquise-Mimoyeques and at Wizernes - see report No. BBM/7.7 & R.Q.437) indicate that roof falls occur in tunnels when the radius is up to 20 ft., it may be concluded that tunnels in ground such as that at Montrichard, and with similar overhead cover, could be blocked by Tallboy (M).

1.6 Rochebon

.1 Description

These tunnels, at Vauvert, near Rochebon, which are near the right bank of the Loire about 6 miles above Tours, could not be inspected inside owing to the absence of the French military guard in possession of the key to the wooden entrance doors. Conversation with other members of the guard, and with local French civilians, elicited the following -

The part of this tunnel system used by the Germans extends 300-400 m. into the hillside, and consists of three straight tunnels which diverge from the double entrance. A cross gallery at the inner end connects the three tunnels and is about 40 m. long. The cross section of each tunnel is about 5 m. wide and 4 m. high. Lorries can enter a short distance as far as a loading bay. The overhead cover is nearly all soft limestone. ("Pierre friable", "pierre de manier", "pierre tendre"), with very little top soil, the thickness over the tunnels varying from 30 to 35 m.

The Germans used these tunnels for storing bombs and other munitions in the same way as at Montrichard, walling off connexions to the rest of the very extensive system of tunnels. Early in August, 1944, the Germans prepared to demolish the tunnels and their contents by placing at various points fourteen 1000 kg. bombs, wired up ready for firing, each bomb being surrounded by 250 to 350 boxes containing 500 kg. bombs (without detonators). On 10th August, 1944, a French colonel, with the assistance of a local civilian (who imparted this information to the investigating party) made a breach in the enclosing wall within the tunnels, entered the German section, and removed the detonators ("désamorcer"?) from the fourteen large bombs. This was not discovered by the Germans, their guards in the tunnels being kept well supplied with Vouvrays (a local champaigne) so that when they tried to blow the tunnels prior to their final departure on 3rd September, the demolition was averted. At the time of our visit on 9th March, 1945, these tunnels remained stocked with munitions as left by the Germans.

.2 Conclusions

The entrance to tunnels used for storing ammunitions, as at Rochebon and Montrichard, even without camouflage, would probably be difficult to discover from air cover, since they are similar to many thousands of entrances to caves and tunnels in the very extensive troglodyte regions bordering the Loire river, and the Vienne, Cher and other tributaries.

Air attack with Tallboy (M) would probably cause local blocks in the tunnels where the thickness of overhead soft limestone cover is less than about 125 ft. (Note: this was not exceeded at the two places observed as having been used for large munition stores by the Germans in this region). On the other hand local blockages would not necessarily put a large proportion of the dépôt out of action.

Blast attack on entrances would not be likely to be catastrophic; but blocked entrances would delay ingress and egress of munitions until a new entrance had been made through a suitable unused tunnel - an undertaking which might not entail more than a few days work.

1.7 St. Frost

.1 Description

A brief visit was made on 11th March, 1945, to the tunnels at St. Frost, which are situated on the left bank of the Seine river, about 10 miles downstream of Chartres. The Germans had used these tunnels for storing munitions, and had prepared to demolish them.

The storage section comprises one straight main tunnel 6.5 m. wide by about 5.5 m. high rectangular section, with concreted floor, from which run side galleries and bays of similar size, giving an average total width of about 50 m. Lorries could unload under cover inside the entrance.

In the various side tunnels and bays there are about 20 concrete foundations measuring approximately 15 ft. x 15 ft. x 1 ft. 6 in., having cupped recesses in the top which, local French said, supported large aluminium tanks, the latter having been removed in lorries by the Germans when they left. Since a quantity of pressed metal auxiliary petrol tanks for aircraft were observed it is possible that the tanks were used principally as an aviation petrol store.

Various German munitions remain in these tunnels, including crated and uncrated 50 kg. S.D. bombs, S.A.A., crated Sprengbrand C.50, B.1.E and B.2.E-2 incendiary bombs. The latter appear to be in a dangerous condition; indeed, the local gendarme stated that lives had been lost through an explosion which occurred when children were playing in these tunnels after the Germans left (there is a roof and wall fall nearby which has the appearance of having been caused by an internal explosion). One Tellermine (T.M.42 Stahl) was noticed.

The entrance to these tunnels is closed with barbed wire, though not very securely.

.2 Conclusions

There was no evidence of air attack on the vicinity. The thickness and nature of the overhead cover are such that roof falls would probably be caused by 1000 lb. M.C. delay fused bombs.

1.8 Baimbert (St. Pierre)

This forward V.1 bomb store, about 10 miles north-east of St. Pol (Pas de Calais), is approached by a concrete road about half a mile long. That part of the tunnel system which could be inspected consists of four tunnels driven into rising ground (marly chalk), with cross galleries (see Photograph No. 15). The entrance tunnels, which vary in width from 10 ft. 3 in. to 8 ft. 4 in. and in height from 9 ft. 10 in. to 8 ft. 4 in., run straight into the hillside for about 85 ft., and are lined with concrete. The wall lining is of pre-cast concrete blocks 18 in. thick; the roof is arched, the lining being in-situ concrete 16 in. thick.

Beyond the lined sections all tunnels were found to be blocked by roof falls which, according to local inhabitants, were caused by the removal of timbering, since the Germans left, by a coal mining company for use as pit props.

The overhead cover rises to about 20 ft. at 25 ft. from the entrances, and is not much more over the storage part of the tunnels inspected where it was estimated that there is about 5 ft. of top soil over 15 to 20 ft. of chalk.

The site had been bombed, a direct hit having obliterated one of the tunnel entrances (see Photograph 16). However, no hits appear to have been made over the tunnelled area, the subsidence in the surface above almost certainly being due to the roof falls which occurred on removal of the timbering.

The inhabitants stated that the Germans launched the V.1 bombs from a wood at Parfay, about half a mile from the tunnels, that an appreciable proportion of the bombs exploded soon after launching, and that launching site was demolished by the Germans the day before the British Army arrived in September, 1944.

1.9 Thil (near Longwy)

.1 Location

An underground V.1 bomb factory was established by the Germans in an iron mine in the Ardennes-Lorraine border. The site is at Thil, and is reached by a road which follows the valley of the river Meuse. The mine is situated in the

The mine, the commercial name of which is "la Mine de la Concession de Tiercelot à Thil", was worked until March, 1944, when it was taken over by the Germans.

.2 Description

The Germans set up the factory in a portion of the mine where the existing galleries were large enough for machine shops, etc., the only structural work involved being the laying of concrete floors. A plan of the layout is shown in Fig. 5, which together with Figs. 4, 6 and 7 were prepared from plans supplied by the French officials at the mine.

The cutting leading to the entrance, which has reinforced retaining walls from 5 ft. to 8 ft. 10 in. thick by 12 ft. 3 in. high, is shown in Photograph No. 17, and in Fig. 4. The reinforcement projecting from the tops of the retaining walls suggests that for a distance of about 90 ft. from the entrance a reinforced concrete slab was to have been constructed over the top.

From Fig. 7 it is evident that it was intended to run a standard gauge railway track a distance of about 1800 m. into the main entrance tunnel to a transhipment station. The tunnel had been widened at two places for the construction of loading bays, but owing, it was stated by the French, to hurried work roof falls had occurred, causing tunnel blocks at both places.

Sections through the mine are shown in Figs. 4 and 6, whence it is seen that the overhead cover varies from 36 ft. at the tunnel entrance to about 250 ft. over the factory area.

Inside the machine shops and storage galleries items observed included drills, lathes, milling machines, welding plant, grinders, paint sprayers, and various V.I. bomb components such as wing sections, pressed steel body sections, assembled tail units, compressed air spheres, warheads (without charges), and numerous unidentified small parts (Photographs Nos. 18 - 22). Other installations observed were overhead ventilating ducts, compressed air and water pipes, and electricity cables. Electric power was said to be supplied by overhead cable from Migeville, but the key electric plant for the area was at Pierres, 32 kg. from Thil. No provision for emergency power supply was seen in the mine.

There were no protective doors at the tunnel entrance, but the great length of the approach tunnel, and the general layout of the galleries in the factory area would have greatly reduced any blast effects in the factory from explosions in or near the tunnel entrance.

On the surface above the factory area of the mine work had been started on nine vertical shafts, the largest of those seen being 14 ft. 7 in. by 13 ft. 1 in. section inside timbering (Photograph No. 24). The plan details of the top of another of these shafts is shown in Fig. 4 (Photograph No. 23). These shafts were also being driven upwards from the tunnels below, and falls had occurred at some of them. It seems possible, in view of the single entrance tunnel, that these large shafts may have been intended, apart from ventilation, to augment the means of ingress for raw materials and egress for finished products.

It was stated by the French that no less than 80 of these shafts were projected; but this should be accepted with reserve.

In addition to the 9 vertical shafts under construction a completed steel-lined inclined chute from the surface down to the tunnels was noted. This was used for aggregates required for concrete work.

.3 Labour

According to the French chief d'exploitation of the mine about 5000 persons were employed on V.I. bomb manufacture in the mine on a three 8-hour shift system. It was said that the total number of workers was to have been increased to 15,000. The chief d'exploitation stated that the Germans had been given the order to produce 1000 bombs per day, but that they had not been able to do so.

.4 Conclusions

The cover over the factory area and the rester part of the entrance tunnel is much too thick for penetrating bombs of any type in operational use to have caused any damage in the tunnels.

In air attack on similar places there is the possibility of bombs falling down open shafts, and if fuzed for long delay (e.g. 11 sec.) serious damage might result. However, in the case of this factory in the Thil mine, with its uncompleted shafts and single entrance tunnel, at least a temporary stoppage of production would have resulted from blocking the entrance cutting and tunnel portal, for which purpose 500 or 1000 lb. M.C. or G.P. bombs would have sufficed. The entrance tunnel itself was probably vulnerable to Tallboy (H) in the first 400 or 500 ft. of its length, where the overhead cover is not excessive. Nevertheless, the blocking of the entrance would not have taken very long to clear - certainly not more than the 3 weeks which it took the Germans to clear the Saumur railway tunnel block (see Report No. BBRM/P.12 "R.C.440"); moreover, there exist other entrances to the mine which might have been adapted and used in an emergency. On the whole, it would seem that air attack on such underground factories where the overhead cover is invulnerable, attention should be paid to entrances, access roads and railways, and to sources of power supply (e.g., in this case to the Pienne power station).

.5 Geological note on the ironstone mines at Thil

The Upper Lias of Lorraine contains a rich bed of ironstone which is worked over a wide area both in galleries and in open quarries. The ironstone formation includes, besides the mineral layer the Micaeous Marls (5 m. - 25 m.) above and Upper Liassic Shales with Pyrites below (1 m. - 25 m.). The formation is lenticular, varying considerably in thickness and in its constituent beds. At la Côte Rouge it is 27 m. thick and is composed of five beds, all worked, making a total of 16 m. of mineral ore. At the other end of the Longwy Basin, near Garey it is not more than 4.65 m., and appears as a single bed. Generally the rock tends to be siliceous in the west and calcareous in the east.

The ironstone is present as colitic grains and is usually exploited when in a bed more than 1.75 m. thick, containing 30 per cent iron, with some latitude according to whether the non-ferrous mineral is calcium carbonate or silica. In the Briey basin there are six beds, named from the top down, Red, Red, Red, Yellow, Grey, Black, Green. Usually only one Red bed is present, the Yellow may be missing and often also the Black and Green. The Grey bed is the most regular and is normally the thickest and richest. It varies in thickness from 1.80 m. to 3.60 m., and generally yields 30 - 40 per cent iron in 2 m. - 4 m. thickness. Richer beds are known but they are the exception.

The ironstone mines at Thil are galleries driven into the hillside south-west of Thil to exploit that part of the field underlying Tiercelet. The succession in this area is as follows:-

- Pliocene - 3) Muds & gravels
- Jurassic - 2) Bajocian (average 50 m.)
 - a) Saccharoidal & Coralline limestones
 - b) Colitic & crystalline yellowish or rust coloured limestones
 - c) Granular, shelly & sandy yellowish limestones with marly intercalations
 - d) Grey and Blue marls
 - e) Limestones
 - f) Colitic ironstones
 - g) Peat & shales
- Jurassic - 1) Upper Lias

2. CONCLUSIONS

The principal conclusions to be drawn from this report are with regard to the types of underground places the Germans used for manufacture and storage, the thickness of overhead cover in various soils which were considered adequate, and what form of air attack would be likely to prove the most effective. For this purpose an analysis is given in Appendix A (Table I).

At seven of the nine places inspected existing quarry tunnels had been adapted, and of these seven only the relatively small munition and petrol store in the chalk tunnels at St. Prest had overhead cover of a thickness likely to be vulnerable to bombs in operational use smaller than the Tallboy (M) 12,000 lb. Incidentally, the use of existing tunnels has the additional advantage of making air cover identification more difficult, particularly in riverside localities such as those bordering the river Loire and its tributaries, where all suitable cliffs and hillsides are riddled with troglodyte workings.

The V.1 bomb factory in the iron mine at Thil, in Luxembourg, may be considered to be proof against any bomb in so far as damage to the tunnels by bombs penetrating the ground above is concerned. In such a case it would appear that to attack entrances, communications and sources of power supply is the only method justifiable.

In the case of munition and oil stores with a penetrable thickness of overhead cover it may well be preferable to design the attack with a view to bombs detonating within the tunnels, rather than to cause spalling or tunnel blockages. For example, whereas a 1000 lb. M.C. or G.P. bomb exploding in the ground above the St. Prest tunnels would probably have caused a blockage, a 2000 lb. S.A.P. bomb might perforate by impact, and even the comparatively small charge should result in serious secondary effects in view of the nature of the contents of the tunnels.

On the other hand, the cover over the munition store in the Rochebon tunnels is too great to have been perforated by impact, so in this case the choice is between blocking the tunnels by Tallboy (M), and attacking the entrance with smaller bombs.

TABLE I
ANALYSIS OF VULNERABILITY TO AIR ATTACK

Purpose	Overhead cover	Description	Thickness (ft.)	Whether bombed	Vulnerability, min. size of bomb to split tunnels by high level attack	Blast protection on near entrance	Remarks
7.1 bomb forward store	Chalk	over 100	No	Tallboy (M) 12,000 lb.	Traverse walls at entrance		Tallboy (M) over tunnelled area might have been effective. Otherwise, attack on entrances & communications with smaller bombs seems to be indicated.
7.1 bomb, subsequently 10.000 lb. store	Soft Limestone	80	Yes	do.	Good, owing to doors at main entrance, & ramifications of tunnels layout		Tallboy (M) hits over the tunnelled area would have caused roof falls. Blocks, however, would not have stopped all activity owing to ease of going round blocks.
7.11 - silo	do.	100	No	do.	None to main entrance tunnels		Blast bombs near entrances would have effect in the long straight entrance tunnels, but machine shops in side tunnels would be protected by the ramifications of the layout.
7.11 - silo	silos	65 - 80	No	do.	None at entrance, but ramifications give good protection		Tallboy (M) could have caused roof falls; in places blow-throughs resulting in serious blast effects within the tunnels might have occurred.
7.11 - silo	silos	do.	100	No	do.	None	Air attack on the entrance with both blast & penetrating bombs might have been more effective weight for weight, than Tallboy (M) attack over the tunnelled area.
7.11 - silo	silos	do.	40 - 65	No	1000 lb. M.C. or G.P.	None	Owing to proximity to the entrance of the small area used blast attack on the entrance might have been effective.
7.11 - silo	Chalk	20 - 25	Yes	500 lb. M.C. or G.P.	None		Of the 4 entrances one was demolished by a direct bomb hit. No hits over the tunnelled area were seen.
7.11 - silo	Limestone & Ironstone	250	No	No bomb effect	None		Best to attack entrances, communications and sources of power supply.

APPENDIX B

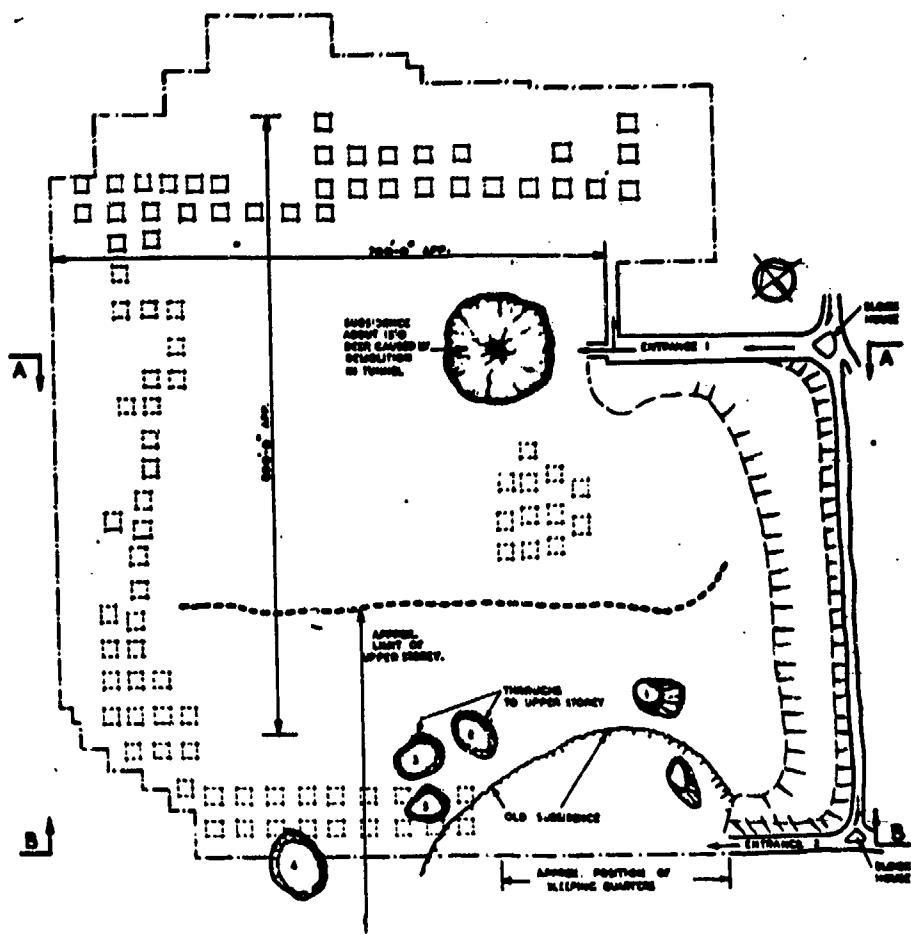
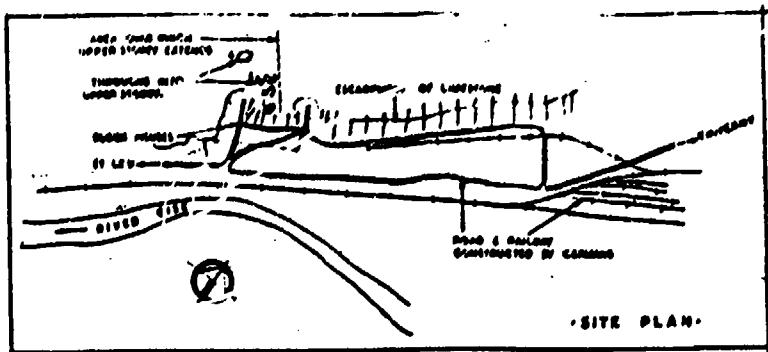
LIST OF PHOTOGRAPHS

No.	Place	Date	Caption
1	St. Leu d'Esserent	Feb. 1945	Panorama showing approach road and escarpment. Gun emplacement on left.
2	St. Leu d'Esserent	Feb. 1945	Main entrance to lower level tunnels. The actual entrance seen is blocked, but there is another opening on the right (see Photo. No. 3).
3	St. Leu d'Esserent	Feb. 1945	Main entrance to lower level tunnels, showing evidence of hit on cliff face by small bomb which threw down one of the heavy concrete doors (see also Photo. No. 2).
4	St. Leu d'Esserent	Feb. 1945	An entrance to the upper level tunnels.
5	St. Leu d'Esserent	Feb. 1945	Crater No. 2. Subsidence to upper level tunnels. ²
6	St. Leu d'Esserent	Feb. 1945	Crater No. 3. Subsidence to upper level tunnels. ²
7	St. Leu d'Esserent	Feb. 1945	Crater No. 4. Subsidence to upper level tunnels. ²
8	St. Leu d'Esserent	Feb. 1945	Crater No. 4. Subsidence to upper level tunnels. ²
9	St. Leu d'Esserent	Feb. 1945	Trolleys for V.1 bombs in lower level tunnels.
10	St. Leu d'Esserent	Feb. 1945	Roof fall onto V.1 bomb inside lower level tunnels caused by enemy demolition.
11	Trossey-Maximin	Feb. 1945	General view of shafts under construction. Note shallow depth of cover over tunnels.
12	Trossey-Maximin	Feb. 1945	Close-up of shaft showing reinforcement being erected for thick reinforced concrete walls and roof, suggesting an underground storage tank.
13	Tavernay	Mar. 1945	Twin entrances to the tunnels used by the Germans for S.K.F. ball-bearing manufacture.
14	Montrichard	Mar. 1945	Entrance to munition store, partly demolished by the Germans by internal charges which blew through to the surface above.
15	Raimbert (St. Pierre)	Mar. 1945	Two of the four entrances to underground V.1 bomb store.
16	Raimbert (St. Pierre)	Mar. 1945	Underground V.1 bomb store. The entrance on the left was demolished by a direct bomb hit.
17	Longwy (Thil)	Mar. 1945	Entrance cutting, showing concrete retaining walls, and tunnel entrance to iron mine used by Germans for V.1 bomb factory.
18	Longwy (Thil)	Mar. 1945	End of electric railway at about 2 km. from entrance, at beginning of V.1 bomb factory area.
19	Longwy (Thil)	Mar. 1945	Machin shop. Note unlined tunnels.
20	Longwy (Thil)	Mar. 1945	V.1 bomb tail units.
21	Longwy (Thil)	Mar. 1945	V.1 bomb body sections.

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- 13 -

No.	Place	Date	Caption
22	Longwy (Thil)	Mar. 1945	7.1 bomb warheads. Wing unit on right.
23	Longwy (Thil)	Mar. 1945	Top of nearly completed shaft down to 7.1 bomb factory in iron mine below. Eight such shafts were observed, though it was said that about ten times this number were projected.
24	Longwy (Thil)	Mar. 1945	Top of one of the largest of the 8 shafts (14 ft. 7 in. x 13 ft. 1 in. clear). The purpose of these shafts, apart from ventilation, may have been for ingress of raw materials and/or egress for fabricated parts, since there appeared to be only one main entrance tunnel.



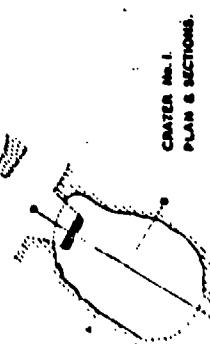
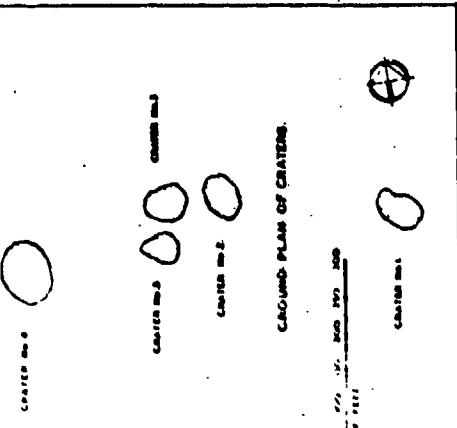
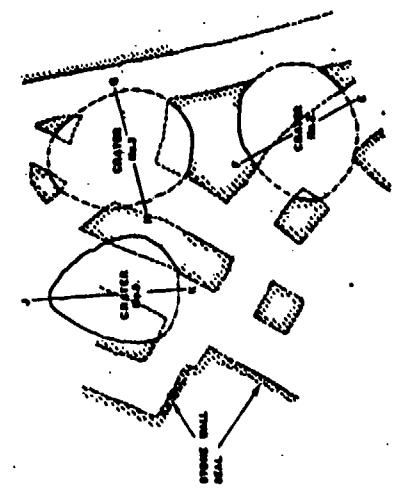
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PLAN OF CRATERS NO. 1-3-4.
SHOWING BREAKS THROUGH INTO UPPER LEVEL TUNNELS.
3. APPROX. TUNNEL LENGTH AT BREAKS.

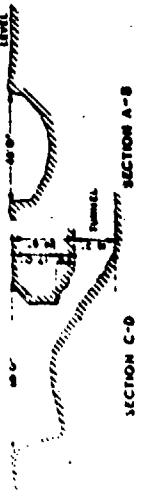
SOLID ROCK MASS OF UPPER LEVEL TUNNELS

— BREAKS TO TUNNELS VISIBLE FROM CRATERS

PLAN OF CRATER NO. 4



Crater No. 1.
PLAN & SECTIONS.



Crater No. 2.
PLAN & SECTIONS.

SECTION C-B CRATER 2.

SECTION C-B CRATER 4.

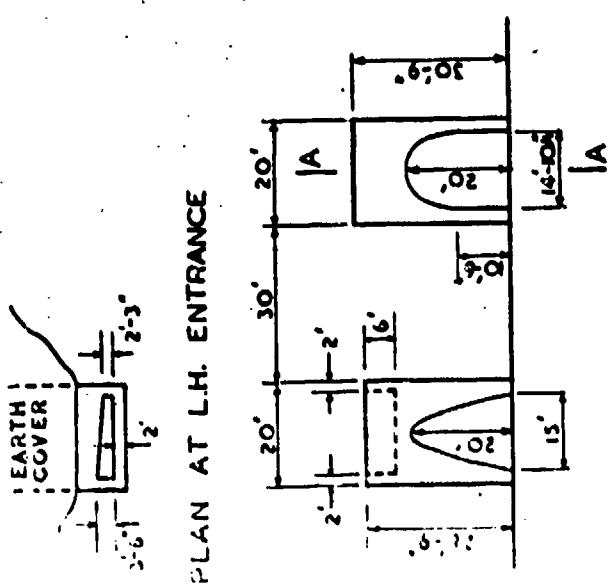
SECTION J-K CRATER 3.

SECTION J-K CRATER 4.

NOTE. THIS SURVEY WAS MADE ABOUT 6 MONTHS AFTER THE ATTACK. THE CRATERS HAVING BEEN ENLARGED BY SUBSIDENCE INTO UPPER LEVEL TUNNELS.

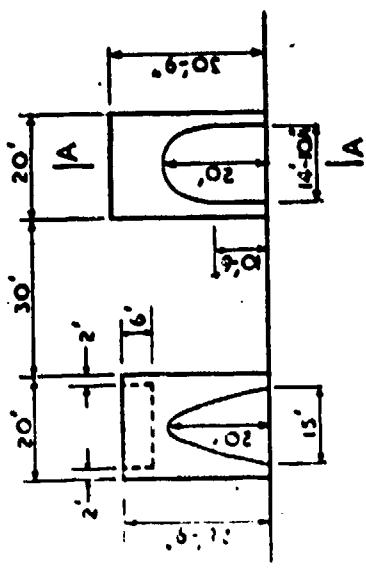
0.25 0.50 0.75 1.00 1.25
SCALE OF FEET

G. 2. ST. LEU D'ESSERENT — SURVEY OF SELECTED CRATERS.



SECTION A-A

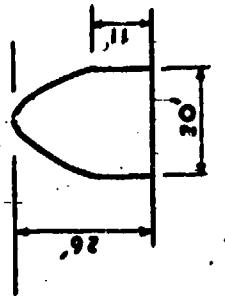
PRESUMED
THICKNESS



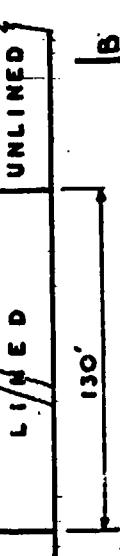
SECTION A-A

10 0 10 20 40 60 80 100
SCALE OF FEET

SECTION B-B



100' COVER APPROX.
N.T.S.



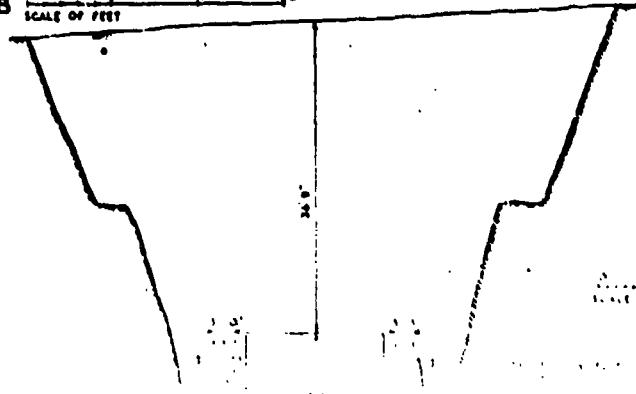
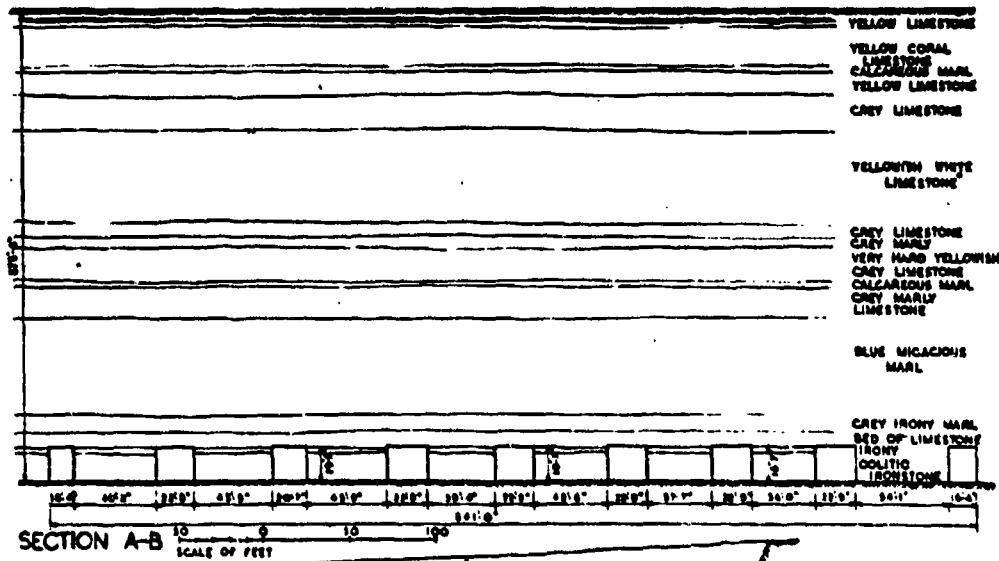
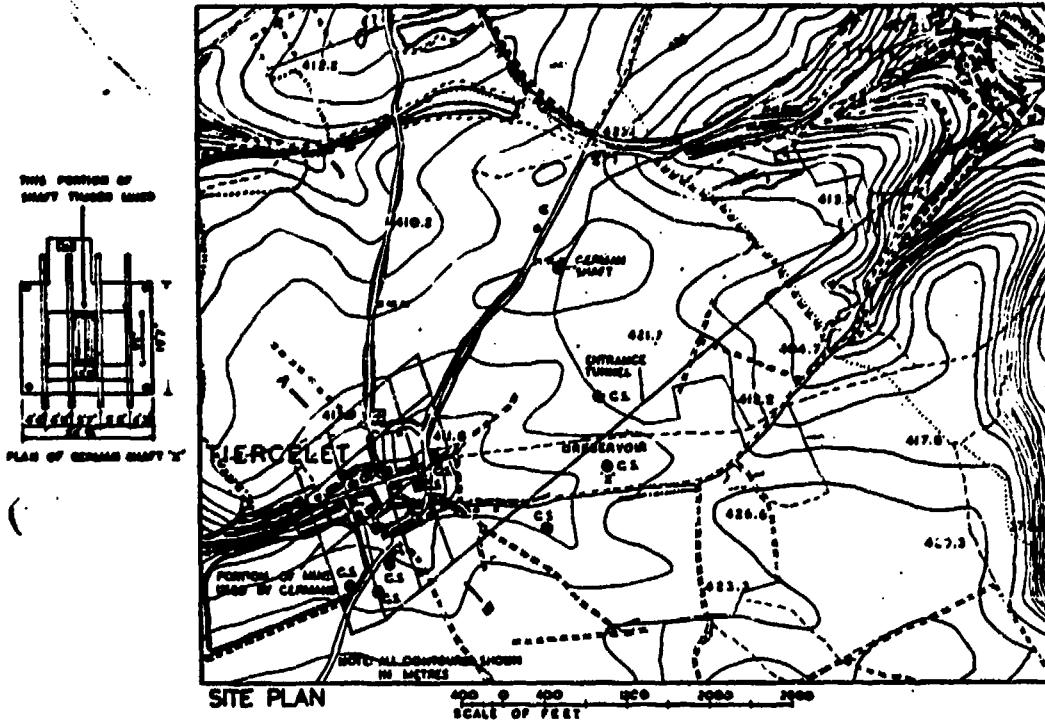
1.5.2.3.1963.

3. TAVERNEY—SKETCH DETAILS OF TUNNELS AT ENTRANCE

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UNDERGROUND V.I. FACTORY AT THI.

IRONSTONE MINE



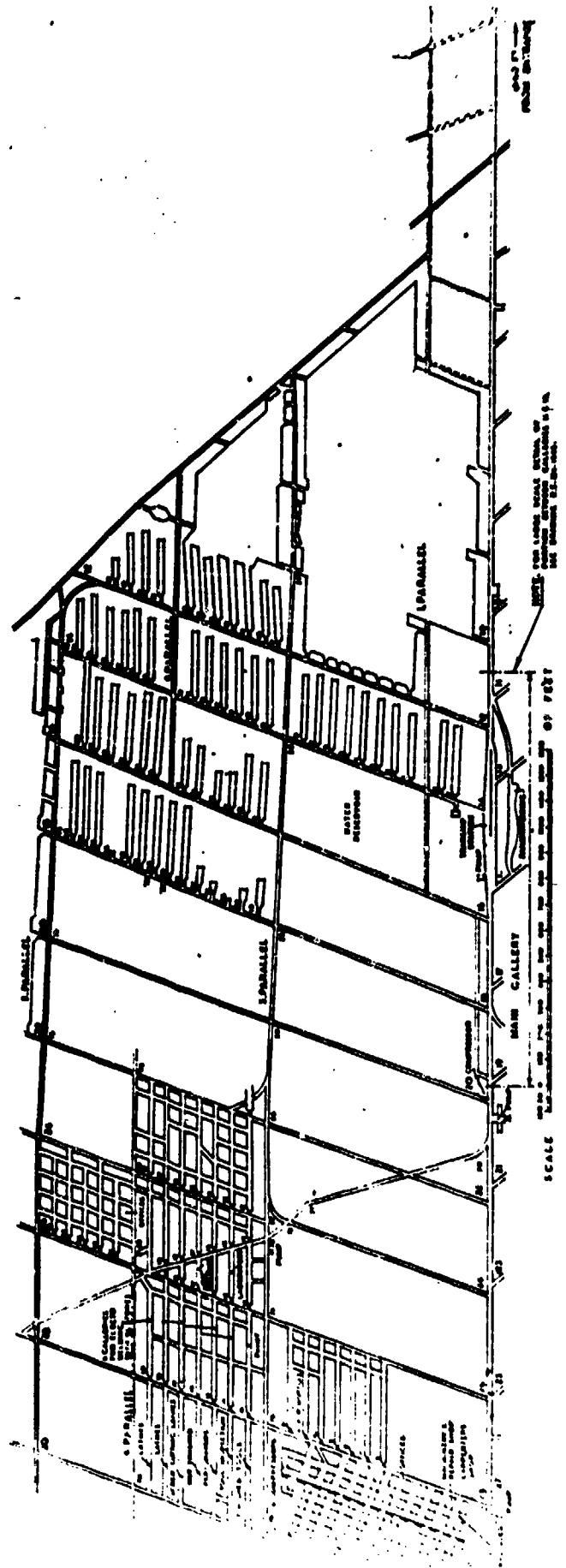


FIG. 5. UNDERGROUND V.I. FACTORY AT THIL.
LAYOUT PLAN.
(IRONSTONE MINE)

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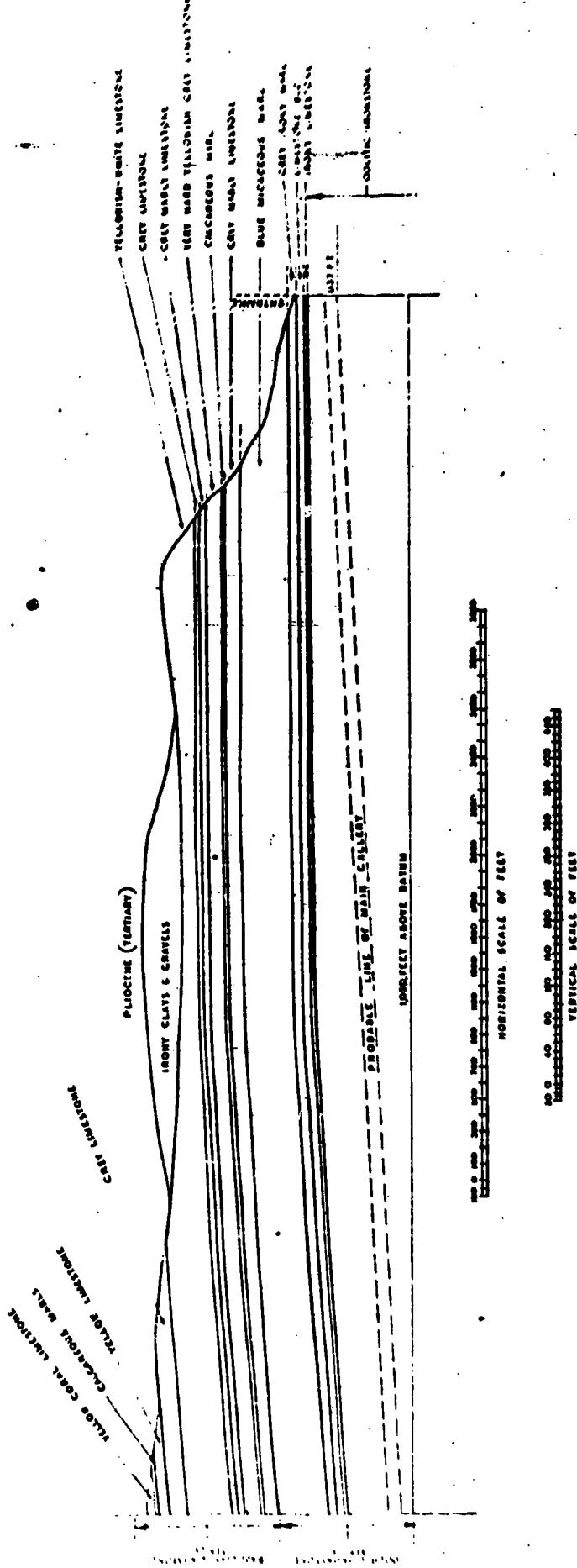


FIG. 6. IRONSTONE MINE - THIL - LONGITUDINAL SECTION THROUGH
MAIN GALLERY
(UNDERGROUND V.I. FACTORY AND STORES)

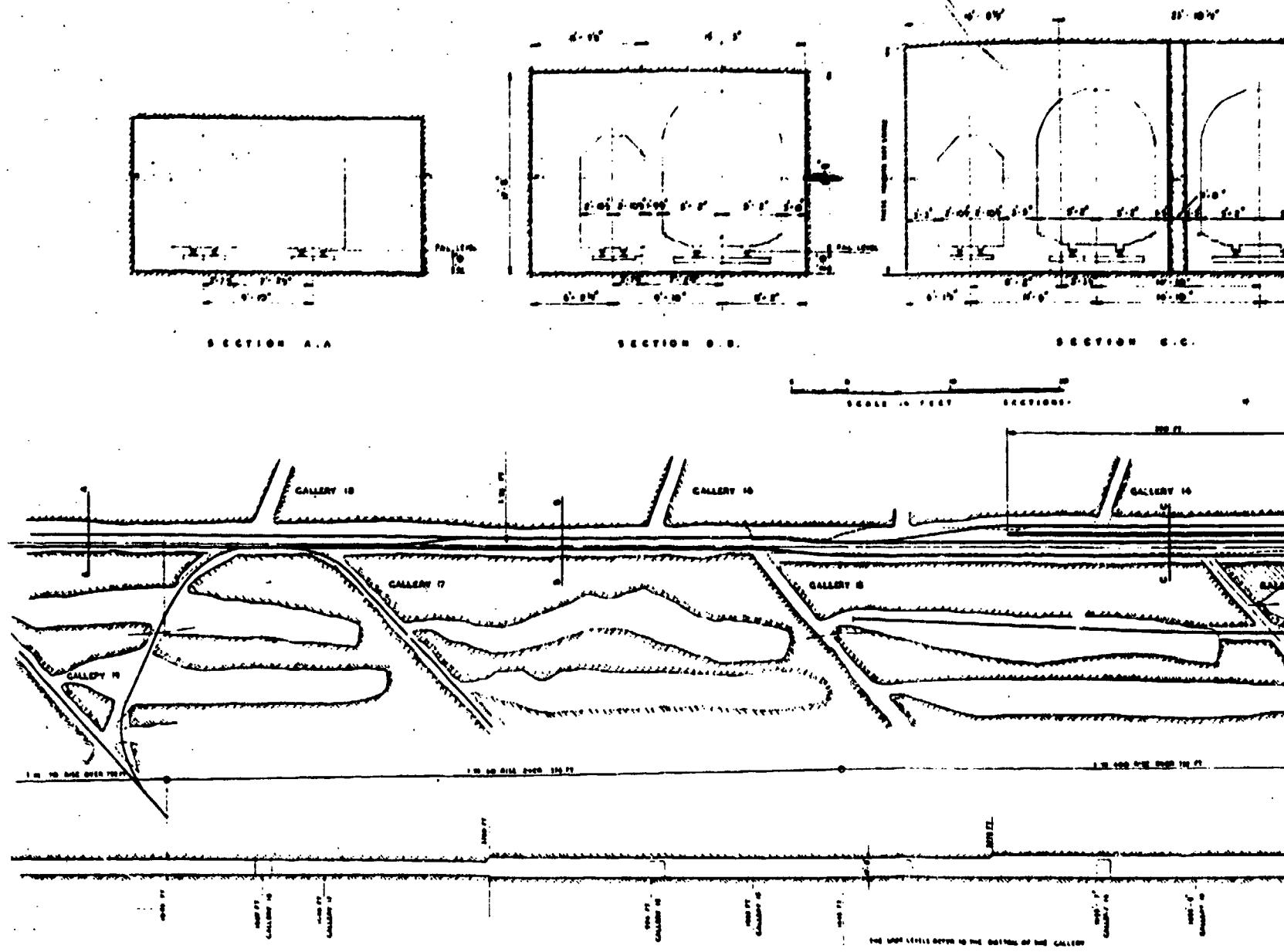
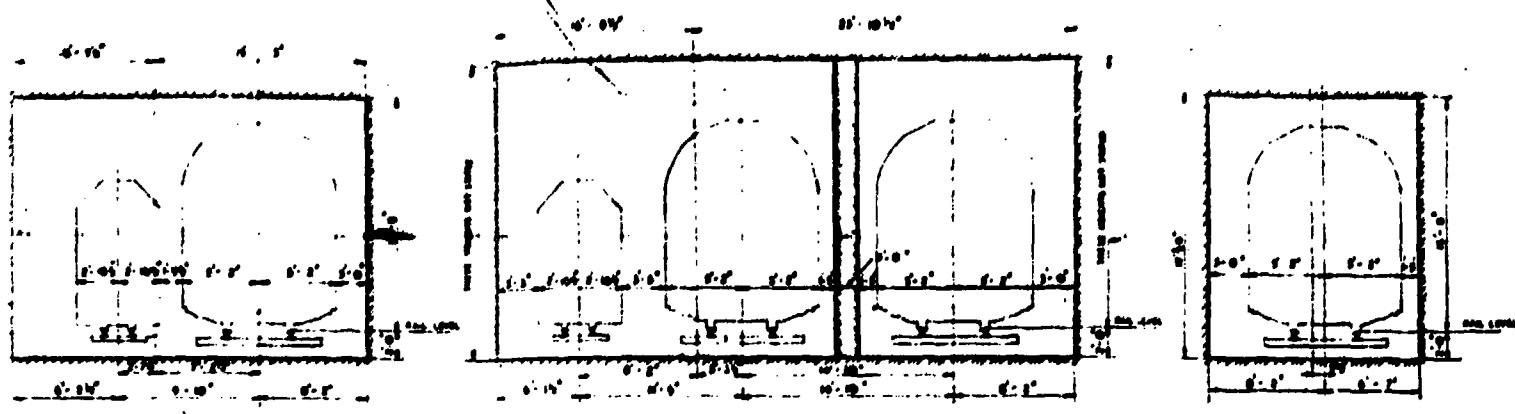
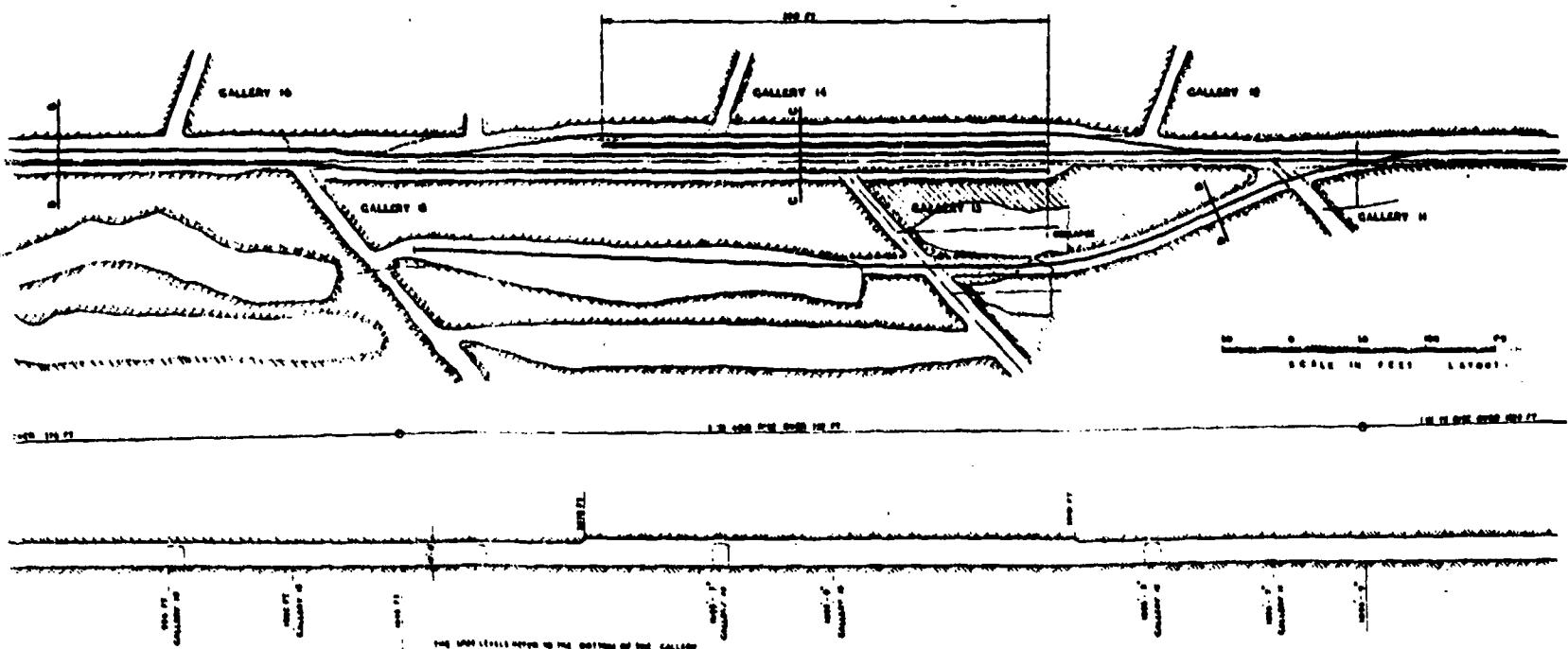


FIG. 7.

UNDERGROUND V.I. FACTORY AT THIL . . . GERMAN PROPOSAL FOR TRANSHIP ST



SCALE IN FEET SECTION



THE NUMBERS REFER TO THE BOTTOM OF THE GALLIES

DRY AT THIL . . . GERMAN PROPOSAL FOR TRANSHIP STATION

RECEIVED



Photo 1. Panorama showing approach road and escarpment. Gun emplacement on left.



Photo 2. Main entrance to lower level tunnels. The actual entrance seen is blocked, but there is another opening on the right (see photo No.3).



Photo 3. Main entrance to lower level tunnels, showing evidence of hit on cliff face by small bomb which threw down one of the heavy concrete doors (see also Photo No.2).





Photo 6. Crater No.3. Sub-sidence to upper level tunnels.



Photo 7. Crater No.4. Sub-sidence to upper level tunnels.



Photo 8. Crater No.4. Sub-sidence to upper level tunnels.



Photo 9. Building for V.I. bombs in lower level tunnels.





Photo 13. Close-up of shaft showing reinforcement bars protruding from thick reinforced concrete walls and roof, suggesting an underground storage tank.



Photo 15. Two of the four entrances to underground V-1 bomb store.



Photo 13. Open entrances to the tunnels used by the Germans for S.A.F. tanks in Normandy.



Photo 14. Entrance to munition store, partly demolished by the Germans by internal charges which blew them to the surface.





Photo 17. Entrance cutting,
showing concrete retaining walls
and tunnel entrance to iron mine
used by Germans for V.1 bomb
factory.

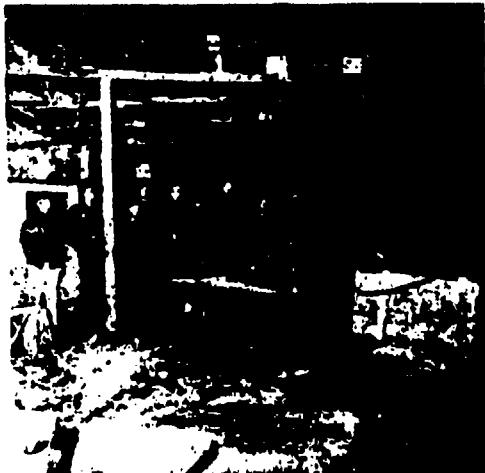


Photo 18. End of electric rail-
way at about 2 km. from entrance,
at beginning of V.1 bomb factory
area.



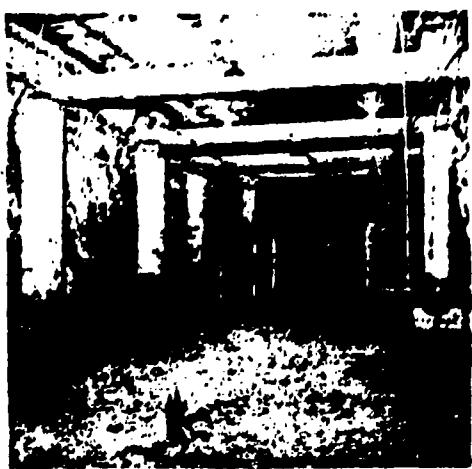


Photo 20. V.1 bomb tail units.

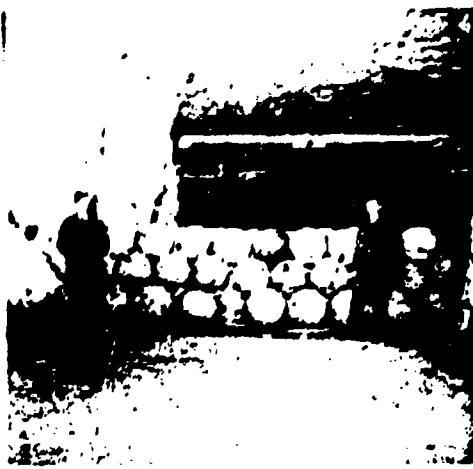


Photo 21. V.1 bomb air bottles.



Photo 22. V.1 bomb warheads.
Wing unit on right.

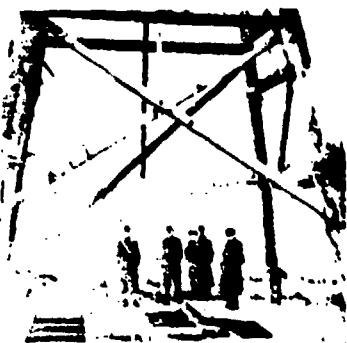


Photo 23. Top of a nearly completed
V-1 launching site. Note the large
air bottle on the right.

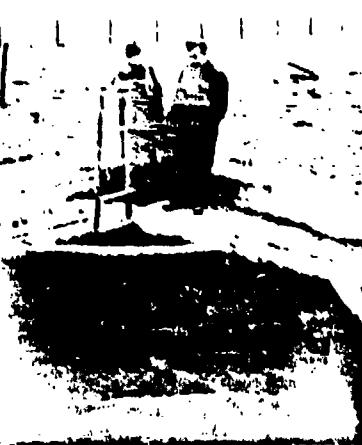


Photo 24. Top of one of the large air bottles
for the V-1 bombs. (11 ft. 7 in. x 16 ft. 1 in.)

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This refers to our letter to you dated October 7, 1999, regarding your appeal to the Information Security Oversight Office for 14 documents previously requested under Mandatory Declassification Review procedures. One document (AD346727) was provided to you by our letter dated November 19, 1999.

The review of 11 British documents you requested is complete and there are no objections to release. Titles of these documents are contained on the enclosed sheet and a copy of each is enclosed. We will advise you as soon as the reviews of the remaining two documents are completed.

Per DOD letter,
Please mark these 11
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to the public."

I verified the docs
could be marked
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DOD Security Review,
695-9556/6428 on
21 Jan 2000.

Sincerely,

SIGNED

H. J. McIntyre
Director

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